The Development and Design of a Training Mock-Up for Smart CCTV

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ABSTRACT

The rapid advancement of AI-enhanced Smart CCTV systems has created a growing demand for technicians skilled in installation, configuration, operation, and troubleshooting, yet structured hands-on training tools remain limited, particularly in technical-vocational education. This study aimed to develop and validate a Smart CCTV Training Mock-up with accompanying instructional materials for Bachelor of Technology and Livelihood Education (BTLED) students. Employing a developmental research design with a quantitative approach, the study purposively selected 39 fourth-year BTLED Industrial Arts students, five instructors, and a panel of Subject Matter Experts (SMEs). Data were gathered using a Needs Assessment Questionnaire (4-point Likert scale) and an Expert Validation Rubric (5-point Likert scale) and were analyzed using frequency, percentage, mean, and standard deviation. Results revealed that students lacked sufficient hands-on exposure to Smart CCTV systems and considered troubleshooting among the most difficult competencies to master, while all eleven proposed hardware, software, and networking components were rated Very Important (M = 3.67-3.83). Expert validation yielded Very Good to Excellent ratings for the prototype across technical accuracy, instructional design, and safety, and for the instructional materials across content, clarity, and usefulness, with technical accuracy attaining the highest means (M = 4.60). The findings indicate that the developed mock-up is both technically appropriate and educationally effective, offering a validated, cost-effective tool that bridges theoretical instruction and applied competence in intelligent surveillance technology.

Keywords: Smart CCTV, training mock-up, instructional materials, technical-vocational education, expert validation, BTLED

INTRODUCTION

The rapid advancement of artificial intelligence has transformed video surveillance from passive monitoring into smart, proactive systems capable of recognizing faces, detecting anomalous behaviors, and alerting operators to potential threats in real time (Ambika et al., 2025; Buradkar et al., 2023; Duong et al., 2023; S.S. et al., 2025; Sonavane et al., 2025). Traditional approaches relied heavily on human operators watching multiple feeds, a practice prone to fatigue, distraction, and delayed responses (S.S. et al., 2025). Smart CCTV systems now underpin public safety and urban security infrastructure, with intelligent video analytics increasingly deployed across transportation hubs, schools, and critical facilities (Konda, 2023; Kumari, 2024). Anomaly detection and activity recognition are among the most actively researched capabilities of these systems, relying on deep learning models to identify suspicious events that human monitoring typically misses (Duong et al., 2023; Suganthi et al., 2024). In smart city environments, CCTV networks are no longer standalone tools but integrated components of IoT-enabled urban data ecosystems (Kencono & Ahsany, 2023; Myagmar-Ochir & Kim, 2023), with edge-based video analytics enabling real-time situational awareness across large-scale camera deployments (Zhang et al., 2019).

However, the very sophistication of these technologies creates significant demands on the workforce that deploys, configures, and maintains them. Electronics technicians require specialized installation, maintenance, and entrepreneurship skills to utilize CCTV systems effectively (Okwelle & Abam, 2019), while the expanding smart-technology landscape has opened new training gaps across technical occupations in domains such as IoT, automation, and cybersecurity (Karapidakis et al., 2025; Ullah et al., 2023). Operators likewise need sustained attention, situational awareness, and rapid decision-making abilities that can only be developed through practical exposure. At the same time, AI-enabled surveillance raises ethical and privacy concerns—particularly around the collection and storage of personally identifiable information—that technicians must understand to configure and manage systems responsibly (Ardabili et al., 2023). Despite these requirements, structured and hands-on training tools for Smart CCTV remain limited, and the resulting skills gap may compromise proper system operation and reduce effectiveness in security-sensitive environments.

Existing studies have widely discussed the technical capabilities of Smart CCTV systems in smart cities and IoT networks (Herlian et al., 2025; Kencono & Ahsany, 2023; Myagmar-Ochir & Kim, 2023), as well as the ethical and privacy concerns related to their use (Ardabili et al., 2023). In parallel, prior research has established that training mock-ups are effective instructional tools in technical-vocational education. Mock-ups of electrical wiring installations, for instance, have been rated acceptable and technically feasible as instructional materials by experts from both academe and industry (Pereyras, 2020), and laboratory diagnostic trainers have demonstrated their value as teaching aids in electronics (Suffian et al., 2024). Similar studies on vehicle and electrical mock-ups report significantly higher learning gains, as well as improved student participation, knowledge retention, and skill acquisition (Sanidad & Alopo-Op, 2025; Solidor & Enteria, 2025). Simulation-based and blended learning approaches have likewise been shown to enhance practical skill performance in vocational education (Qi et al., 2026; Setiawaty & Tjahjono, 2025), allowing learners to practice repeatedly and interact with systems without real-world risks. Yet limited studies have focused on the development and validation of a Smart CCTV Training Mock-up specifically designed for technical-vocational education, and researchers continue to note the lack of structured training platforms that allow learners to safely practice real operational tasks in a controlled environment.

This gap is particularly significant for senior high school and tertiary students in technical-vocational tracks, which were introduced specifically to equip learners with job-ready, industry-aligned competencies (Bank, 2021; Dernbach, 2020). The track, designed to cultivate demonstrable skills and competencies for the global workplace (Castillo et al., 2019), serves a substantial share of students nationwide (Ramos, 2021) and integrates TESDA-accredited programs that enable students to earn nationally recognized certifications, such as National Certificate II, as evidence of industry readiness (Bank, 2021; O et al., 2026). Technical-vocational education is widely recognized as crucial for workforce readiness and youth employability—yet its implementation is frequently constrained by shortages in equipment and consumables for practical training (O et al., 2026). While contemporary commercial surveillance increasingly incorporates cloud-based video management, AI-driven anomaly detection, and multi-camera emulation networks, vocational institutes often lack the capital to procure enterprise-grade setups. Developing modular, low-cost training mock-ups that mimic these core functionalities provides an essential pathway to align academic training with evolving industry practices.

Therefore, this study aims to develop and validate a Smart CCTV Training Mock-up for Technical-Vocational Education. Specifically, the study seeks to identify the needs and challenges encountered in Smart CCTV training; determine the important components and content for the mock-up; design and develop a functional prototype based on instructional design principles; develop accompanying instructional materials featuring scenario-based exercises; and validate the mock-up in terms of technical accuracy, instructional design, and safety, as well as validate the instructional materials in terms of content, clarity, and usefulness. It is hypothesized that a systematically developed mock-up, grounded in instructional design principles and validated by experts, will prove both technically appropriate and educationally effective for developing competencies in intelligent surveillance technology.

Statement of the Problem

This study aims to develop and evaluate a Smart Closed-Circuit Television (CCTV) Training Mock-up. Specifically, the research seeks to answer the following questions:

1. What are the needs and challenges currently encountered in teaching and learning of the Smart CCTV Training Mock-up?

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2. What components and content are considered important for inclusion in the Smart CCTV Training Mock-up?

3. What is the level of validity of the Smart CCTV Training Mock-up Prototype in terms of:

   3.1 Technical Accuracy,

   3.2 Instructional Design, and

   3.3 Safety?

4. What is the level of validity of the instructional materials in terms of:

   4.1 Content,

   4.2 Clarity, and

   4.3 Usefulness?

METHODOLOGY

Research Design

This study employed a developmental research design utilizing a quantitative approach, following a two-phase process commonly used in educational technology research. Developmental research integrates descriptive research for problem contextual analysis with systems development and formative evaluation (Elgazzar, 2014), typically progressing through sequential stages of defining, designing, and developing a product before expert appraisal (Dewi & Maulida, 2023; Irawan et al., 2018). The first phase involved a needs assessment using a descriptive survey to identify challenges in Smart CCTV training and required components; the second phase focused on the design, development, and expert validation of the prototype and accompanying instructional materials. A panel of Subject Matter Experts (SMEs) evaluated the prototype across technical accuracy, instructional design, and safety, while instructional materials were assessed across content, clarity, and usefulness using a 5-point Likert scale. Descriptive statistics—frequency, percentage, mean, and standard deviation—were used to analyze the collected data.

Research Setting

The study was conducted at the University of Science and Technology of Southern Philippines. The setting was deemed appropriate because the Smart CCTV Training Mock-up is directly relevant to the technical and instructional competencies emphasized in the institution's Industrial Arts program.

Research Participants

The study involved 39 fourth-year Bachelor of Technology and Livelihood Education (BTLED) students majoring in Industrial Arts, five Industrial Arts instructors, and five Subject Matter Experts (SMEs) in Electronics and technical-vocational education. Students and instructors participated in the needs assessment phase, while the five SMEs evaluated the prototype and instructional materials. Purposive sampling was used to select participants based on their direct involvement and background in Industrial Arts and electronics education.

Research Instruments

First, a Needs Assessment Questionnaire (4-point Likert scale) was administered to students and instructors. Scale range for needs/challenges: 3.26-4.00 = Strongly Agree ; 2.51-3.25 = Agree; 1.76-2.50 = Disagree; 1.00-1.75 = Strongly Disagree. For components: 3.26-4.00 = Very Important; 2.51-3.25 = Important; 1.76-2.50 = Slightly Important; 1.00-1.75 = Not Important.

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Second, an Expert Validation Rubric (5-point Likert scale) evaluated the prototype (Technical Accuracy, Instructional Design, Durability/Safety) and instructional materials (Content, Clarity, Assessment/Usefulness). Interpretation range: 4.21-5.00 = Excellent; 3.41-4.20 = Very Good; 2.61-3.40 = Good; 1.81-2.60 = Fair; 1.00-1.80 = Poor. A comment section provided narrative feedback.

Data Gathering Procedure

Following ethical clearance and Informed Consent distribution, the needs assessment was administered. Data informed the construction of the prototype and drafting of instructional manuals. The SME panel subsequently evaluated the physical mock-up and manuals using the structured rubric to guide final revisions.

Data Analysis

Frequencies, percentages, weighted means, and standard deviations were calculated for all Likert items to assess needs, prioritized components, and expert validity scores.

Ethical Considerations

Informed consent was obtained from all adult participants and legal guardians (where applicable). Responses were anonymized, securely stored, and maintained under minimal-risk conditions in compliance with institutional guidelines.

RESULTS

Problem 1: Needs and Challenges in Smart CCTV Training

Table 4: Necessity for Smart CCTV Systems

Item	M	SD	Description
1. Students do not receive sufficient hands-on practice with real Smart CCTV systems	3.24	.821	Agree
2. A portable Smart CCTV training mock-up would impact students' learning experience	3.19	.890	Agree
3. Troubleshooting Smart CCTV system problems is one of the most difficult skills to teach/learn	2.98	.841	Agree
4. Safety or security concerns limit practice on real or simulated systems	3.05	.795	Agree
5. It is difficult to provide standardized Smart CCTV practice activities for all students	3.12	.861	Agree

All five indicators fell within the *Agree* range. The highest-rated item was insufficient hands-on practice (M = 3.24, SD = .821), followed by the positive impact of a portable mock-up (M = 3.19, SD = .890).

Problem 2: Components and Content for the Mock-Up

Table 5: Desired Content of the Smart CCTV Training Mock-up

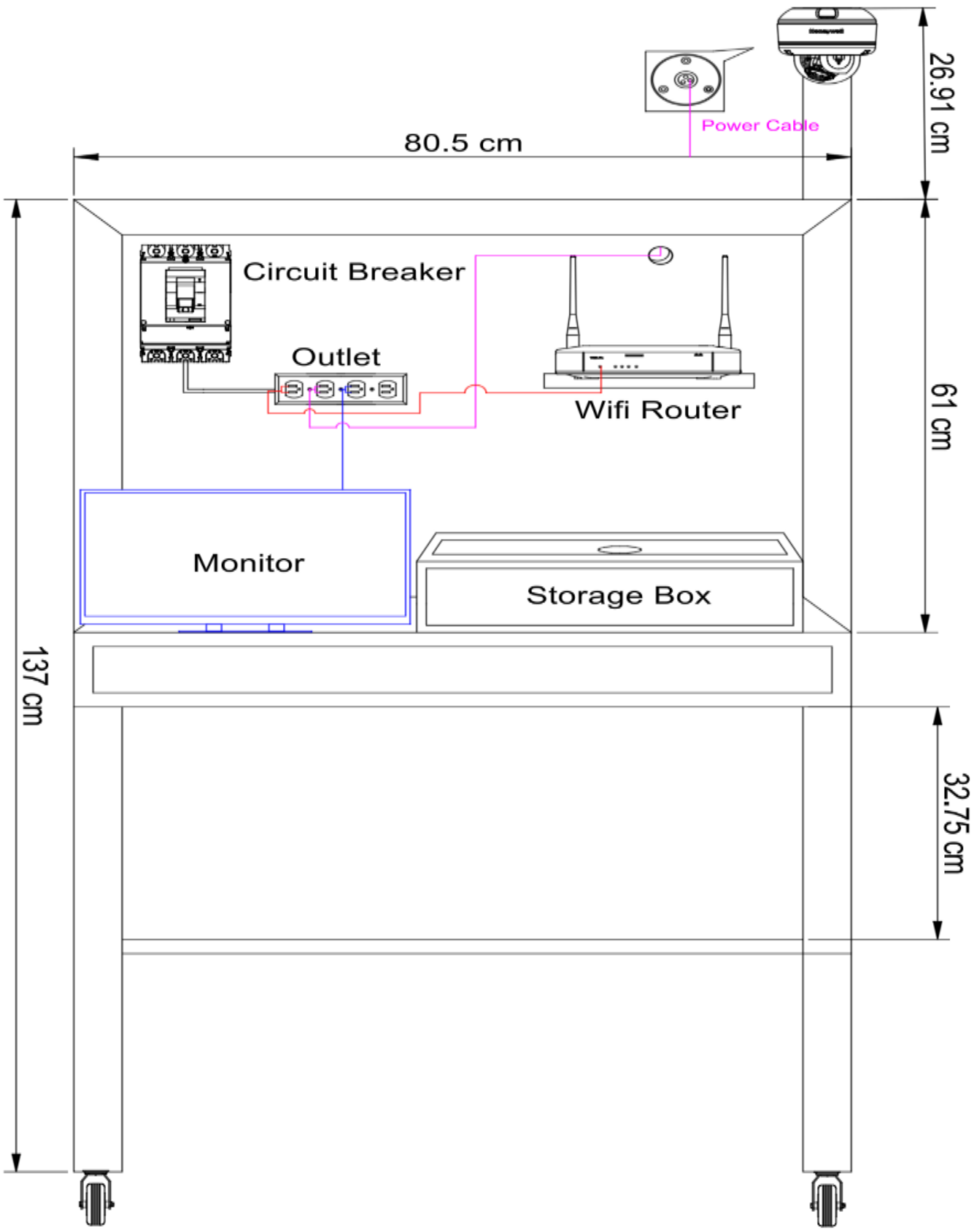
Item	M	SD	Description
1. Smart CCTV Camera	3.71	.457	Very Important
2. Recording Device	3.67	.526	Very Important
3. Cables and connectors	3.74	.497	Very Important
4. TV/Monitor	3.81	.397	Very Important
5. Circuit Breaker	3.79	.415	Very Important
6. System Enclosure	3.69	.468	Very Important
7. Installation and configuration of the Smart CCTV/mobile application	3.79	.415	Very Important
8. Connecting the system to a network/internet	3.83	.381	Very Important

9. Basic system setup and menu navigation	3.79	.415	Very Important
10. Remote viewing	3.74	.445	Very Important
11. Backing up and restoring video data	3.81	.397	Very Important

All items were rated *Very Important* (M = 3.67-3.83), led by network/internet connectivity (M = 3.83, SD = .381).

Problem 3: Level of Validity of the Prototype.

The structural and circuit configuration of the prototype is illustrated in the schematic diagram (Figure 1), showing the integration of the camera, recording unit, network interface, circuit breaker, and power distribution components.



Front View

Figure 1. Schematic diagram of the Smart CCTV Training Mock-up.

Table 6: Technical Accuracy

Item	M	SD	Description
1. The mock-up accurately represents real Smart CCTV systems (cameras, cables, recorder, etc.)	4.60	.548	Very Good
2. Components used are similar to those in actual CCTV installations	4.60	.548	Excellent

Table 7: Instructional Design

Item	M	SD	Description
3. The mock-up is easy to set up, use, and understand for both instructors and trainees	4.40	.548	Very Good
4. Test points, connectors, and controls are clearly labeled and accessible	4.20	.447	Very Good

Table 8: Safety

Item	M	SD	Description
5. The mock-up is safe to use (no high voltage, secure wiring, protected connections)	4.00	.707	Very Good
6. It is built to withstand repeated use in a training environment	3.80	.447	Very Good
7. Cables and components are neatly arranged and protected from damage	4.00	.707	Very Good

Problem 4: Level of Validity of the Instructional Materials

Table 9: Content

Item	M	SD	Description
8. The content matches what the mock-up can do and covers important CCTV topics	4.40	.548	Very Good
9. Instructions explain concepts clearly before hands-on activities	4.40	.548	Very Good
10. Both basic setup and advanced troubleshooting are covered	4.00	.000	Very Good

Table 10: Clarity

Item	M	SD	Description
11. Learning goals for each activity are clear and measurable	4.60	.548	Very Good
12. Step-by-step procedures are easy to follow and in logical order	4.40	.548	Very Good
13. Diagrams, pictures, and labels are clear and helpful	4.40	.548	Very Good

Table 11: Usefulness

Item	M	SD	Description
14. Activities and questions help measure trainee understanding	4.40	.548	Very Good
15. Safety tips and best practices are included	4.40	.548	Very Good
16. The overall materials are effective for teaching and learning	4.40	.548	Very Good

DISCUSSION AND CONCLUSION

Needs and Components

The finding that insufficient hands-on practice was the primary concern (M = 3.24) emphasizes the gap between theory and application in TVET. Troubleshooting difficulties (M = 2.98) further underline the necessity for dedicated diagnostic platforms. High ratings across all 11 proposed components (M = 3.67-3.83) reinforce that modern Smart CCTV instruction must encompass hardware mounting, mobile integration, and network administration.

Expert Validation, Durability, and Cost-Effectiveness

Expert ratings across technical accuracy (M = 4.60), instructional design (M = 4.20-4.40), and safety (M = 3.80-4.00) affirm the prototype's effectiveness. The lower durability rating (M = 3.80) highlights an important practical factor: training boards undergo heavy student handling. Implementing modular component mounting and standardized off-the-shelf wiring significantly enhances cost-effectiveness and replacement sustainability. Low-cost modularity ensures that budget-constrained vocational schools can maintain, repair, and scale the mock-up long-term without requiring expensive commercial service contracts.

Alignment with Emerging Surveillance Trends

While the prototype successfully replicates core operational features (motion detection, app alerts, local recording, network access), enterprise surveillance is rapidly adopting advanced paradigms including AI-driven anomaly detection, cloud management, edge computing, and multi-camera network emulation. To keep pace with industry practices, instructional modules should incorporate scenario-based troubleshooting (e.g., simulating IP conflict resolution, bandwith bottlenecking, and signal loss). Additionally, integrating virtual reality (VR) or digital twin simulations alongside physical trainers offers a hybrid solution to expose students to multi-camera enterprise deployments at minimal cost.

Practical Implications

The validated mock-up offers a cost-effective, replicable model for technical education institutions. It enables instructors to deliver standardized, safe, and hands-on exercises that directly cultivate job-ready competencies.

Limitations

Several limitations should be noted regarding this study: first, the sample size and scope were constrained to a single institution involving 39 students, 5 instructors, and 5 subject matter experts ($N=49$), which restricts broad generalizability across diverse TVET contexts; second, in terms of feature depth, the physical prototype mimics core Smart CCTV functionalities but lacks enterprise-grade features such as multi-camera hardware arrays, dedicated AI edge chips, or integrated cloud infrastructure; and third, the longitudinal assessment was limited to immediate validity ratings rather than tracking long-term learning retention, workplace skill transfer, or graduate employability.

RECOMMENDATIONS AND FUTURE WORK

To extend the impact and applicability of the trainer, future work should focus on: conducting multi-institutional validation studies across diverse vocational schools and student cohorts to establish external validity; expanding physical or software modules through advanced feature integration such as AI anomaly detection, multi-camera networking, and cloud-based video management systems (VMS); undertaking longitudinal studies to evaluate student skill retention and subsequent job performance over extended periods; and enhancing instructional delivery through hybrid and scenario-based learning that supplements physical trainers with VR-based simulations and expanded troubleshooting guides.

CONCLUSION

This study successfully developed and validated a Smart CCTV Training Mock-up and accompanying instructional materials for technical-vocational education. The needs assessment highlighted a clear demand for hands-on, network-integrated training, while expert validation confirmed high technical accuracy, instructional quality, and safety. By providing a validated, low-cost training solution, the mock-up bridges theoretical instruction and practical competence, equipping TVET students with essential skills for modern security technology roles.

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